Decision-Aiding
and Alerting System Development
for Distributed Air/Ground Traffic Management

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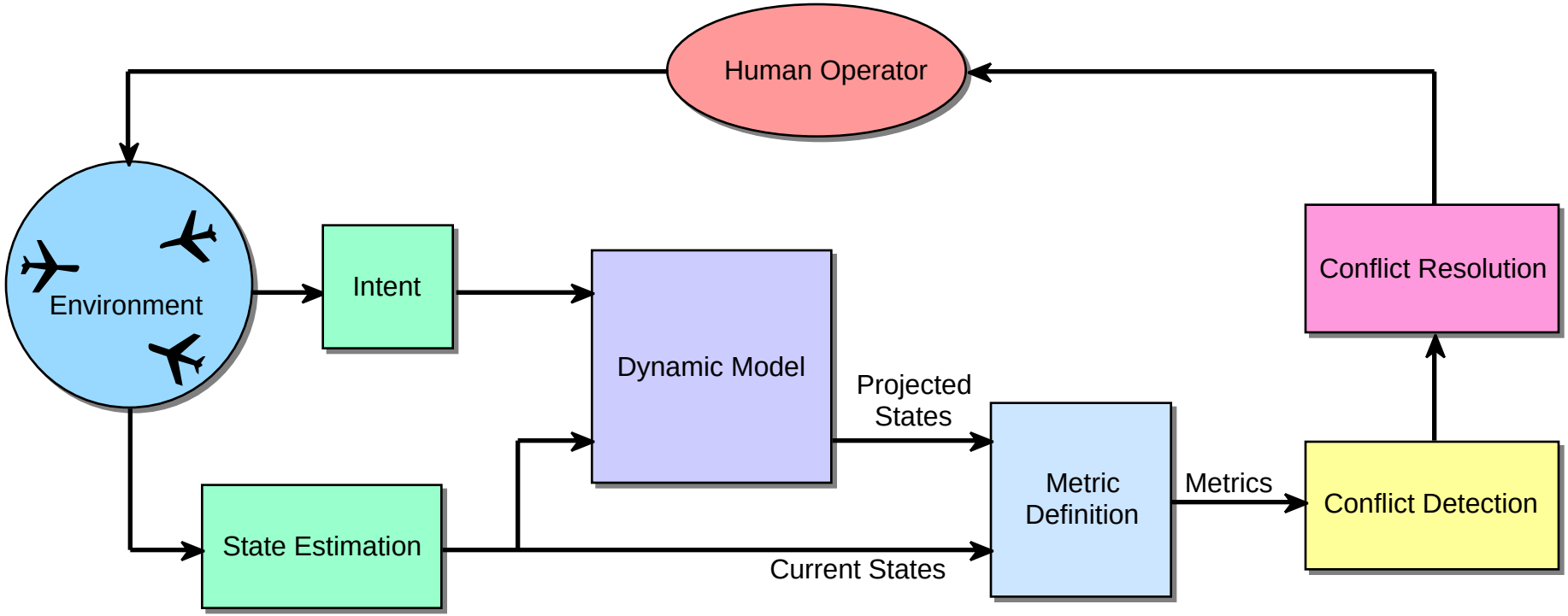
Principal Research Focus

- Fundamental systems-level issues in decision-making with uncertainty
  - Sensors, processing, displays, human factors, procedures
- Projects related to DAG-TM
  - Formal understanding of alerting decision-making
  - Conflict detection and resolution modeling methods
  - Alerting algorithm development
  - Harmonization of multiple decision-making systems
  - Hard / soft hazard modeling

Conflict Detection and Resolution Framework



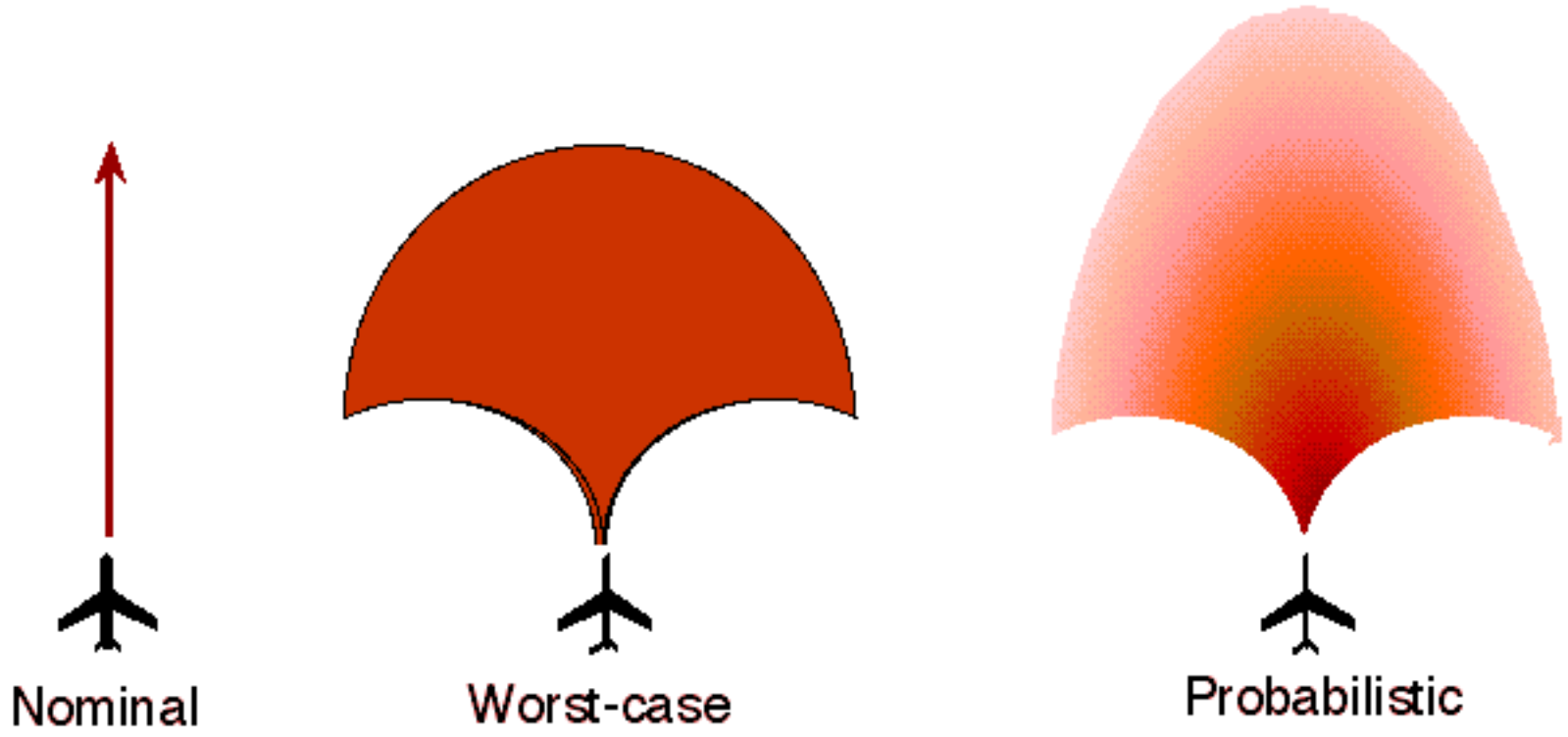
Survey of Conflict Detection & Resolution Methods

- Many groups involved in CD&R; many solution approaches
- 62 models categorized
  - Operational systems (e.g., TCAS, CTAS, URET)
  - Theoretical & prototype models
- Each model examined from viewpoint of CD&R framework
  - Catalogued models, assumptions, metrics, capabilities
- Examined overall system design methods
  - New “Direct Approach” proposed for development
  - Base automated decisions directly on performance metrics

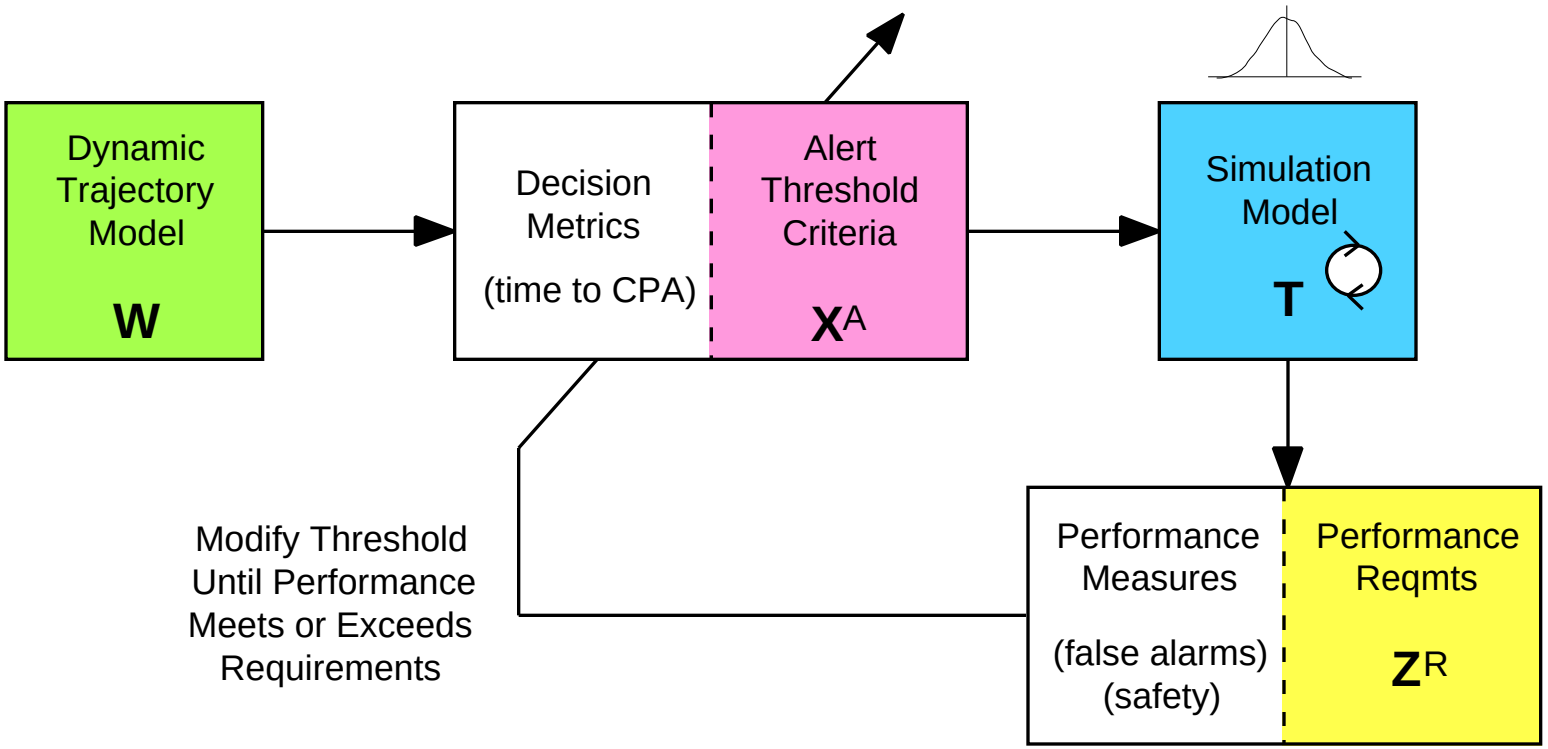
Example Model Categorization

Model	Dimensions	Detection	Resolution	Maneuvers	Multiple
Andrews [32]	H	—	O	T	P
Chakravarthy [19]	H	—	O	C(ST)	P
Tomlin [33]	H	—	O	T	G
Irvine [34]	HV	—	O	C(STV)	P
Ota [35]	HV	—	O	C(TV)	G
Kosecka [36]	H	—	F	C(ST)	G
Zeghal [4]	H	—	F	C(ST)	G
Eby [37,38]	HV	—	F	C(STV)	G
Sridhar [39]	H	√	—	—	P
EGPWS [12]	HV	√	—	—	—
Havel [40]	HV	√	—	—	P
Kelly [3]	HV	√	—	—	P
TCAD [15]	HV	√	—	—	P
GPWS [11]	V	√	P	V	—
PRM [13]	H	√	P	C(TV)	P
Bilimoria [41]	HV	√	P	STV	P
Burgess [42]	H	√	O	TV	P

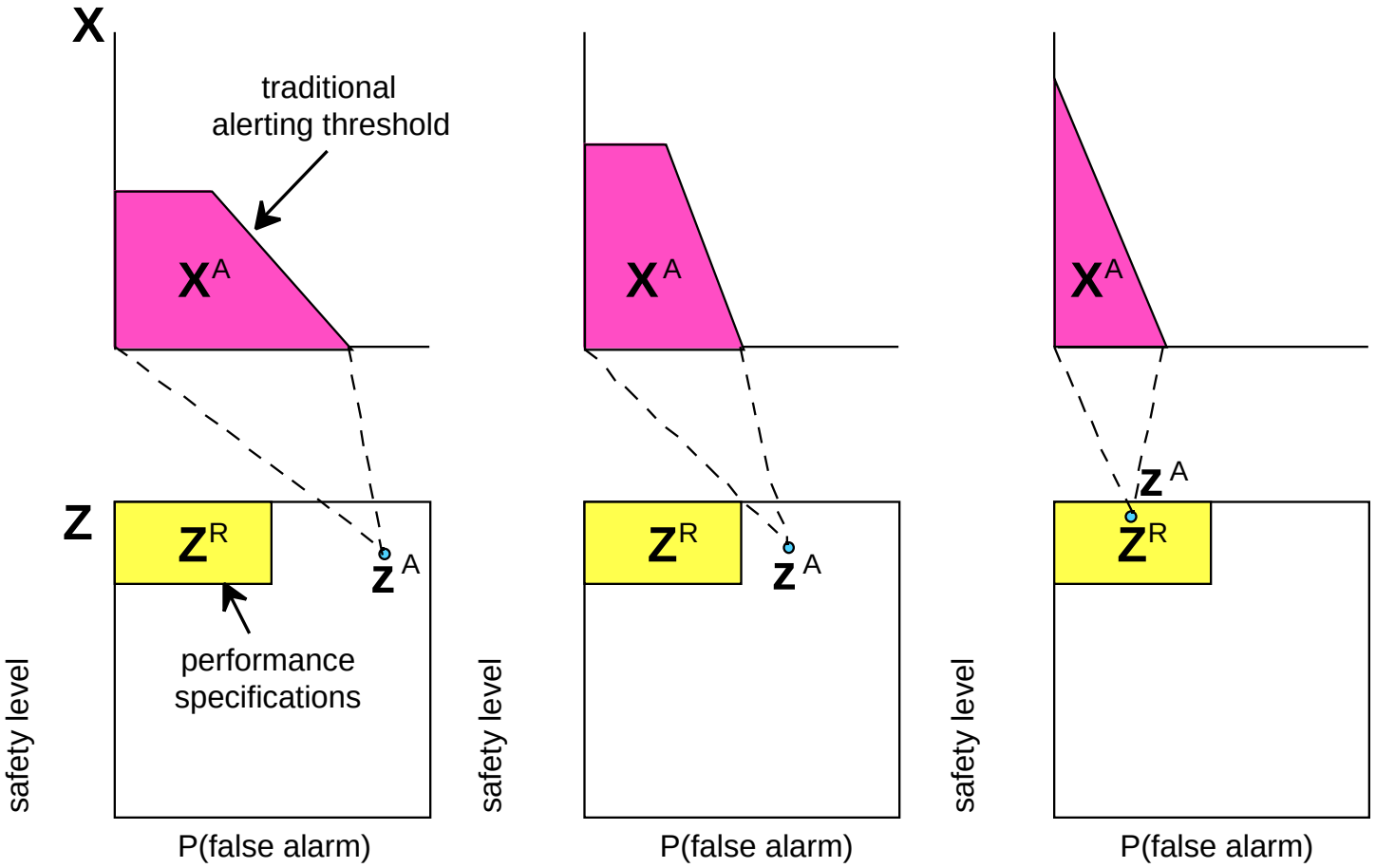
Trajectory Modeling Methods



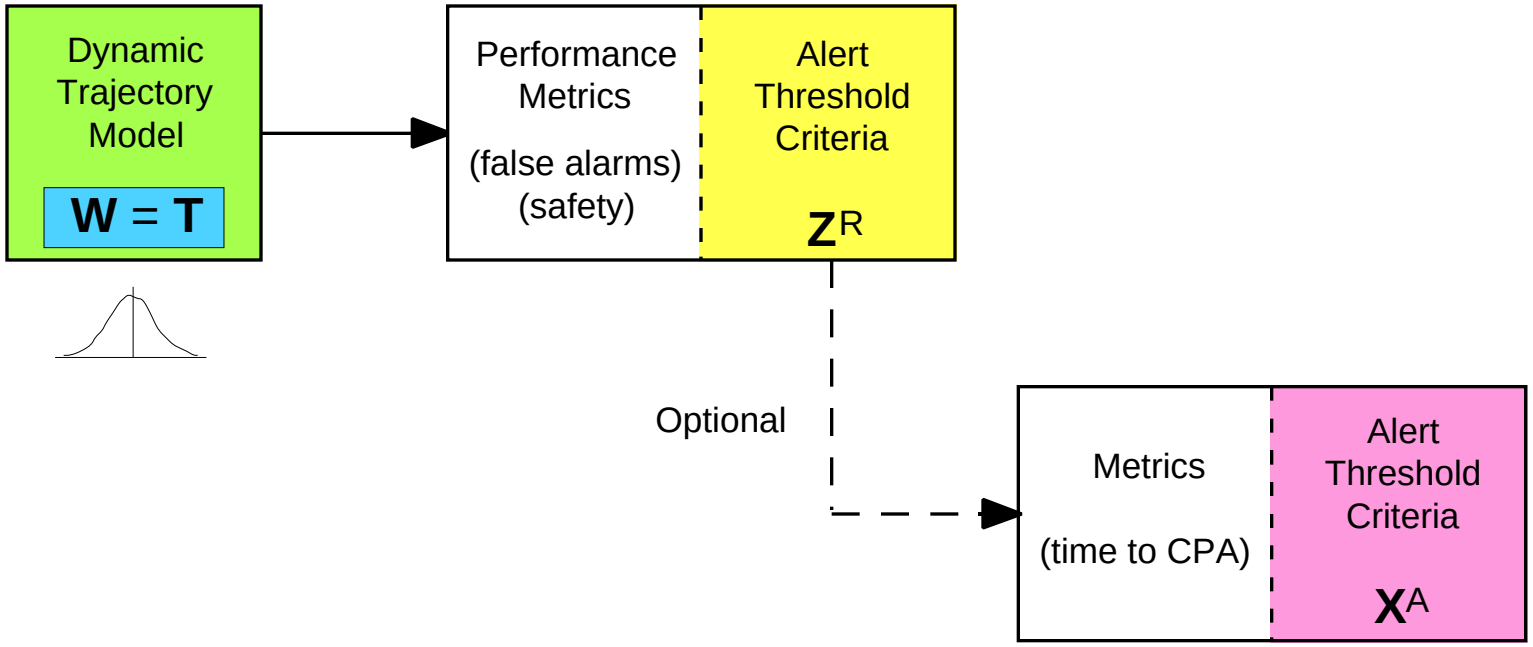
Current Design Method



Mapping Alert Criteria to Performance Metrics



Proposed Direct Approach



Prototype direct-approach CD&R system implemented on NASA Ames 747-400 simulator

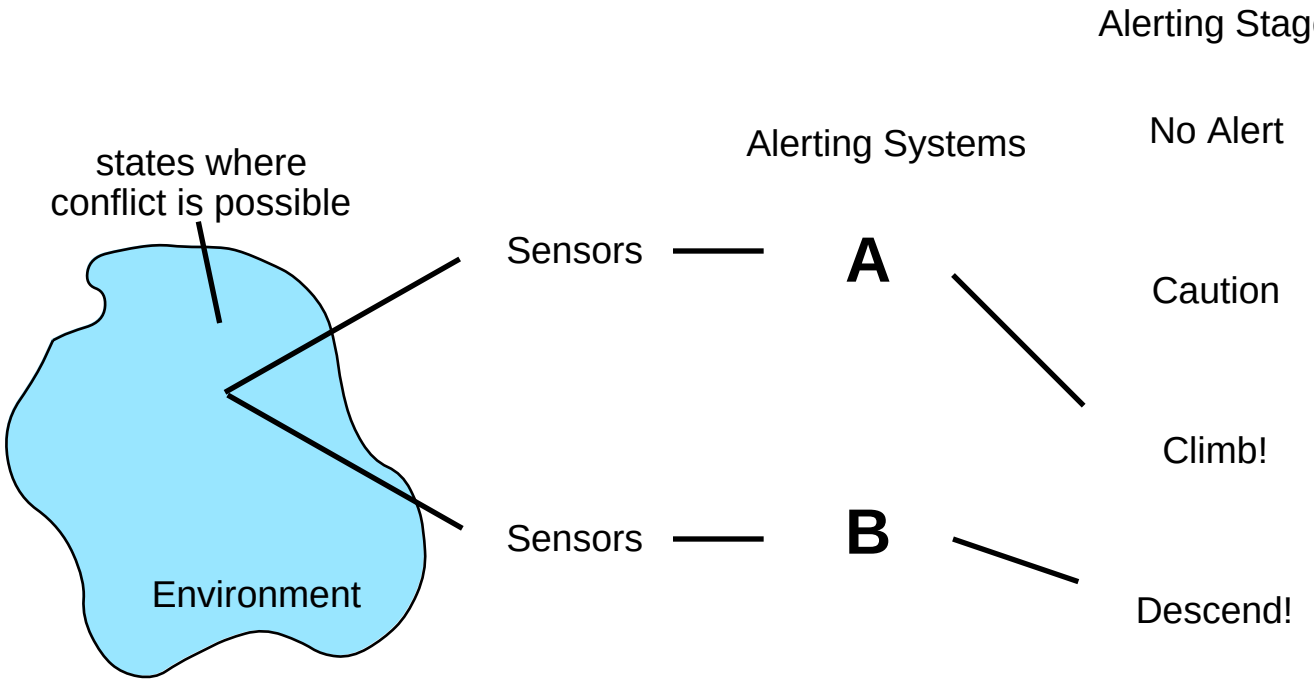
Harmonization of Multiple Decision-Making Systems

- Introduction of independent systems monitoring same situation
  - GPWS → EGPWS
  - TCAS → strategic conflict probes, parallel approach alerting
  - Mixed equipage

- Potential for conflicts between decision support systems
  - Static: system A indicates different threat level than B
  - Dynamic: system A upgrades threat while B downgrades

- Mitigation
  - Prioritization / inhibition
  - Constraints on operation / procedures
  - Modification of system logic

Multiple Alerting System Conflicts



- Developing formal methods for system analysis
- Identification of conflicts and methods to mitigate
- Drivers / implications for human interaction

Hard / Soft Hazard Modeling (I)

- Strategic decision support needs to consider:
  - "hard" hazards (terrain, traffic)
  - "soft" hazards (weather)
  - hard & soft constraints (fuel, time, aircraft performance)

- Traffic conflict prediction
  - Likelihood of hard hazard encounter in future
    - hazard appears to be softer as uncertainty increases

- Weather can be modeled similarly
  - Potential to integrate traffic & weather
  - Improve decision acceptability in regions of severe weather

Hard / Soft Hazard Modeling (II)

- Developing model of pilot acceptance of weather risk
  - Potential use in providing feedback on route acceptability
  - Intelligent pilot model for large-scale traffic simulation
- Preliminary results suggest weather can be adequately modeled as an exposure-time dependent soft hazard
- Mathematical methods for integrating weather & traffic threat have been developed
- Extension to other hazards and constraints (time, fuel)

Key Considerations for the Future

- Interplay of uncertainty and decision-making
  - Balance is critical to acceptance of automated aids
- Development of formalisms behind system design
  - Consistent basis
  - Efficient and effective approaches
- Ability to integrate multiple hazard types, constraints, & players
  - Provide seamless, consistent decision support